LARGE-SCALE PLANNING FOR ASSESSMENT AND RECOVERY OF HUMPBACK WHALE POPULATIONS

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Planning to help humpback whale populations recover from past commercial hunting must acknowledge their seasonal diversity of habitats, frequently governed by different nations, where they are affected by human activities such as shipping, fishing, dredging, waste disposal, and others. Human-induced changes in ocean ecology or resource abundance make it unlikely that populations could regain aboriginal sizes. Comprehensive research programs to assess present distribution and population sizes will usually require coordinated efforts by scientists from many nations. Estimation of present population size is facilitated by seasonal aggregation of whales at feeding or breeding locations, but poor estimation of prehunting abundance make it hard to choose a desired population size or to evaluate present vs past populations. Some populations may require many decades to reach desired population size, owing to the whales' tendency to return to traditional locations and their slow rate of reproduction. Monitoring programs must be long term. The U.S. Humpback Whale Recovery Plan is discussed as an example of a large scale plan covering 3 stocks of humpback whales in two oceans. A research proposal, entitled Years of the North Atlantic Humpback (YONAH), to assess population sizes and movements by an intensive international synoptic study throughout the summer and winter range of the species is summarized.

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The humpback whale, *Megaptera novaeangliae*, was the second species to be protected by the International Whaling Commission, beginning in 1955 with prohibition of commercial (non-subsistence) hunting in the North Atlantic Ocean. Protection was extended to the North Pacific and Southern Hemisphere populations after the 1963 hunting season. The species has not been hunted subsequently except for small subsistence hunts in Greenland (up to 10 per year until 1980 [Kapel, 1979], last whale taken in 1987); Bequia Island, Lesser Antilles (several per year, none caught since 1987 [Ward, 1987; Price, 1985; Adams, 1971, 1975]); and Tonga (up to 10 per year until hunting was stopped in 1978 [Winn and Reichley, 1985]. Winn and Reichley (1985) also noted that at least one humpback was taken by pirate whalers. Forty-one (41) humpbacks were taken in eastern Canada from 1969-1971 by scientific permit (Mitchell, 1973).

Hunting depleted population sizes so greatly throughout their range that Humpback Whales was listed as "Endangered" in waters of the U.S. (Braham, 1984) and "threatened" in Canada (Whitehead, 1987) and are included in Appendix I of the 1973 Convention on International Trade in Endangered Species (CITES).

Classification of an animal as "endangered" entails substantial governmental and scientific responsibilities. In most such cases, active management is required by law, when possible, to facilitate recovery of the depleted population(s). Scientific studies may be required to define more exactly the species' status, potential for recovery, and any actions to be taken. Substantial costs in personnel time and money may be required.

Since the main historical threat to humpback whales, hunting, effectively ended 25 years ago, it might be sufficient to do nothing and simply wait for the protected populations to increase of their own accord. This would be a tempting alternative for governments beset with other acute problems. In the end, time alone might be the most important factor necessary for recovery.

However, a suite of problems that did not exist in the days of hunting now affects some populations of humpbacks and other whales. Many of these threats are much harder to manage than was hunting, and their combined effects could be equally detrimental. These threats are not inten-

tionally directed at humpback whales or other species. Some are unintentional side effects either of longstanding human uses of the sea, such as fishing or shipping, or sloppiness (e.g., pollution by sanitary, chemical or solid wastes). Others involve potential competition between humans and whales for food resources, such as capelin, herring and lately krill, or space, for example where coastal, recreational or industrial development may impact locations used for feeding or breeding (e.g. Nitta and Naughton, 1989).

Some of these threats are subtle and difficult to quantify. Even where effects are dramatic, such as for entrapment or entanglement of whales in fishery gear (Lien *et al.*, 1990) mitigation may be very difficult if no satisfactory alternative methods are available for humans. For example, prohibiting the use of shore-fast nets along the coast of Newfoundland would save the lives of several dozen humpback whales every year, but it would also eliminate the only source of income available to most coastal residents. The cumulative or synergistic effects of different threats, such as food limitation or contamination and challenge by pathogens (Geraci, 1989), are difficult to analyze.

Successful management of the humpback is complicated by their seasonal migrations. During their annual cycle, the whales range through a large geographic area, frequently including waters under the jurisdiction of several nations. Studies sufficiently broad ranging to describe topics such as migration, population structure, or abundance and trends benefit from or require the collaboration by many scientists, often in different countries. Since the whales have relatively long lifetimes, some studies (e.g. investigations on age-specific natality, comparative reproductive fitness, or heritability of behavioral or morphological features) may require decades, sometimes longer than the span of an individual scientific career. Successful incorporation of research results into plans for effective management of the species also faces geographic, temporal and political obstacles. For example, effective management of summer habitats to allow adequate opportunities for feeding is not sufficient to preserve the species if winter habitats for reproduction are not also maintained. Coordination between governments is necessary for management of most humpback whale stocks.

Confounding the issue still further, the terms "management", "conservation" or "preservation" are temporally unbounded. They imply periodic assessment, evaluation and actions to keep a species within certain numeric limits forever. Since natality and mortality vary over time in relation to prevailing ecological forces, management-related research must be carried out at appropriate intervals to determine population sizes and trends. This may become tricky if human-induced mortality causes total mortality to approach natality. In such a situation, and especially in the presence of stochastic factors, it may not be possible at any one time to evaluate whether a population is headed for survival or extinction. Gaskill and Lien (in prep.) emphasized that very long periods may be required to assess the true "health" of a population of whales. Their computer models produced instances in which apparently "healthy" populations went extinct over periods of hundreds of years, even while showing several 50-year periods of steady increase during which scientists or managers would have concluded that the species was progressing wonderfully.

Cautioned by such awareness, management of the humpback whale or of any endangered species cannot be regarded as a task to complete. While there may be some actions that need to be accomplished only once, for example designating certain locations as sanctuaries for the species, other actions may need to be overseen or repeated forever, or until a decision is taken that the species should not be protected.

The following accounts present highlights of two recent approaches to long term, broad scale management or study of humpback whales, namely the U.S. Humpback Whale Recovery Plan and a new research proposal entitled YONAH (Years of the North Atlantic Humpback Whale). Communication of some of the goals, problems and progress of these projects may help them to succeed and may help others to replicate and improve them.

U.S. HUMPBACK WHALE RECOVERY PLAN

The U.S Endangered Species Act (ESA) of 1973, (16 USC 1531 *et seq.*, amended 1978, 1982, 1986) requires Federal agencies to use all reasonable methods available to conserve species of plants and animals that are endangered or threatened with extinction. The U.S. Marine Mammal Protection Act (MMPA) of 1972 (16 usc 1361 et seq., amended 1990) assigned to the National Marine Fisheries Service (NMFS)

responsibility for managing most marine mammal populations, including endangered species.

Section 4 (g) of the ESA requires the Administrator of an agency with oversight responsibility for an endangered species to determine whether populations of that species would benefit from a Recovery Plan, and if so, to construct and implement one. A Recovery Plan is "a guide that delineates, justifies and schedules those actions required for restoring and securing an endangered/threatened species as a viable, self-sustaining member of its ecosystem." Guidelines for constructing Recovery Plans specify that a numerical goal is usually required, along with means for evaluating progress toward achievement of that goal.

In 1987 the Administrator of NMFS concluded that humpback whales would benefit from a Recovery Plan and assigned the NMFS Office of Protected Resources to construct it. An advisory group, the Humpback Whale Recovery Team, was selected by NMFS to assist with the Plan (NMFS, 1990). The 10-person Team included experts on marine mammals from the private sector, academia, and government. Construction of the Plan, now in final stages of approval to become policy for NMFS, required nearly 2 years, 2 team meetings, 7 drafts, and 2 periods for public review and comment.

The Plan concentrates primarily on populations of humpback whales occurring seasonally or permanently in waters of the North Atlantic and North Pacific Oceans under U.S. jurisdiction, but it also includes recommendations for populations using waters around U.S. Trust Territories in the South Pacific. The Plan reviews the natural history of humpback whales; summarizes current knowledge about populations in the North Atlantic Ocean and the North Pacific Ocean; discusses known and potential threats to the species; then details a series of actions recommended to achieve recovery goals and a prioritized schedule estimating the time and money required for those actions.

Defining an overall goal for the Plan was not simple. The objective contained in the recovery planning guidelines, namely restoring the species to be a functional member of its ecosystem could not easily be defined or evaluated, so it would not suffice. The goal of encouraging populations to increase to the abundance prevailing before commercial hunting sounded appealing, but reviewers correctly noted that it might not be possible or desirable, since many other conditions had also changed since hunting began. Some new equilibrium would have to be sought that reflected expanded human use and abuse of the sea, since today's oceans could not support aboriginal numbers of whales as well as increased human populations

The Team then tried to define a suitable percentage of aboriginal numbers for which to strive, but this also proved to be premature. How could one choose such a percentage, or evaluate progress toward that goal, without confident knowledge of prehunting abundance. Despite meticulous historical research (e.g. Mitchell and Reeves, 1983) the few existing estimates of early abundance for the population in the western North Atlantic Ocean were not precise enough to rely upon, and even less information was available for other oceans.

Consequently, the Plan now identifies several longterm goals: (1) the "BIOLOGICAL GOAL" of building and maintaining populations large enough to be resilient to chance events such as epizootics, episodic oceanographic changes, inbreeding or anthropogenic environmental catastrophes; (2) the "NUMERICAL GOAL" of achieving population sizes equal to at least 60% of the historical carrying capacity for populations in the North Atlantic and North Pacific Oceans, since large mammal populations are thought to achieve maximal productivity beginning at approximately that abundance (Fowler and Smith, 1981); and (3) the "POLITICAL GOAL" of being able to reclassify populations of this species from "endangered" to "threatened" or even "unprotected". While tasks identified in the Plan define those longterm goals more precisely, the Plan suggests adoption of an INTERIM GOAL to double the abundance of populations during the next 20 years. Periodic assessments of population abundance are called for in the Plan. Data showing statistically significant trends of population increase overall and reoccupation of portions of the range known to have been occupied during historical times are specified as acceptable evidence of progress toward recovery goals.

Recovery Planning Guidelines require that each action recommended be assigned a priority. Priority 1 denotes an action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future. Priority 2 is an action that must be taken to prevent a significant decline in the species population or habitat quality, or some other significant negative impact short of extinction. Priority 3 is all other actions necessary to provide

for full recovery of the species. According to these guidelines, there is nothing that should (or could) now be done for humpback whales that could be classified as Priority 1. However, many things should be classified as Priority 2.

Actions (tasks) were recommended in four general categories: 1) Maintain and enhance habitats used by humpback whales currently or historically; 2) Identify and reduce direct, human-related mortality, injury and disturbance; 3) Measure and monitor key population parameters; and 4) Improve administration and coordination of recovery efforts.

Foremost among the recommendations for habitat maintainance is identifying and designating critical habitat, particularly in the Hawaiian Islands winter range, but also if needed in other locations. Official designation as critical habitat adds a layer of Federal protection to any area within the jurisdiction of the U.S. This task will require better definition of the habitats and habitat features utilized by humpback whales. Other nations are encouraged to take similar actions to protect humpback whale habitats of special importance, as the Dominican Republic had already done by proclaiming Silver Bank a sanctuary for that species. Studies are recommended to ascertain historical abundance or the potential for reoccupation of habitats that may have been more important to the species in the past and that could be used if populations increase. The development of protocol for monitoring physical and chemical factors that could decrease habitat quality, as well as parasite load, biotoxins, and anthropogenic contaminant levels in tissues of whales and their prey is called for. The Plan recommends reducing disturbance from human- produced underwater noise in Hawaiian waters and in other important habitats whenever humpback whales are present. Finally, recognizing the necessity for providing adequate nutrition for whale populations, the Plan recommends monitoring levels of prey abundance, identifying and evaluating the type and amount of fisheries competition, and preventing the initiation of new large scale fisheries for primary prey of humpback whales.

Foremost among the recommendations designed to identify and reduce direct human-related injury and mortality and perhaps easiest to achieve is continuing the ban on commercial hunting of humpback whales. With luck, this alone might allow recovery of the species throughout its range. However luck cannot be trusted in the face of the various known and potential impacts that have been identified, which include subsistence hunting, entrapment and entanglement in fishing gear, collisions with ships; disturbance from vessels and aircraft; underwater noise from ships, boats and aircraft, commercial whale-watching boats (Atkins and Swartz, 1988: Beach and Weinrich, 1989) and research boats; noise from industrial activities; habitat degradation from chemical pollution, including petroleum; activities associated with increased coastal development; and competition for resources with humans. While some of those impacts might become more severe in the future, the most currently pressing task appears to be working with commercial fishermen and regional fisheries management councils to modify fishing gear and/or fishing regulations, where possible, to prevent entrapment or entanglement of humpback whales. Further evaluation of the effect of collisions with ships on humpback populations is also called for. Improved protocol for reporting and investigating carcasses, stranded specimens, and for photographing living whales will all help to provide information needed for these and other tasks.

Important recommendations for measuring and monitoring key population parameters include re-analyzing existing data with improved techniques; systematizing sampling methods for estimating population size; and developing better facilities for obtaining, archiving and analyzing data on humpback whales. Research vessels need to be dedicated to studying humpback whales and other endangered species, by building a new vessel for use in the North Pacific and another for the North Atlantic Ocean, and/or by chartering existing vessels. New field studies on population dynamics are recommended to examine age-specific rates of birth, survivorship and mortality. Better definition of geographic subdivisions of populations are called for, both by analyzing and evaluating existing information and by implementing immediately initial surveys of selected regions. Migration routes and transit times need to be defined more precisely by using long-term radio tags, underwater listening stations and genetic techniques. Finally, better assessments of abundance, status and trends of humpback whale populations are called for through new census surveys, participation in international sightings surveys and implementation of improved sampling programs for capture-recapture studies using individual identification photographs.

Of foremost importance to the objective of improving administration and coordination of the humpback whale recovery program will be selecting a Director for the overall recovery effort. Expansion or reconstitution of a Recovery Implementation Team to include wider representation of agencies such as the Mineral Management Service and National Park Service, and preparation of detailed regional work plans will improve the Plan's chance of success.

An important recommendation is to encourage multinational cooperation to protect humpback whale habitats. Discussing the Plan at international meetings; distributing it to other countries and providing appropriate follow-up communication; integrating recommendations with goals of the International Whaling Commission; and encouraging other nations to develop recovery plans for conservation and management of humpback whales are important long term goals that will benefit the species.

This sounds like a tall order, especially since NMFS, like most government agencies, is already overburdened and underfunded. Some of the recommendations in this Plan might conflict with those in other plans. For example, maintaining large populations of sand lance, herring and capelin for humpback whales could conflict with goals of the Right Whale Recovery Plan if the fish competed with right whales by consuming too many copepods. NMFS is also preparing a plan for managing shark populations, some of which are under heavy fishing pressure. Some of the sharks thus saved will probably eat young humpback or right whales. How all of this will work out remains to be seen.

YONAH (YEARS OF THE NORTH ATLANTIC HUMPBACK)

As demonstrated above, two simple questions need to be answered as a prelude to successful management of a species. Where are they? and How many are there? Answers remain elusive for most species of cetaceans. Fortunately those questions are somewhat easier to answer for humpback whales than for other balaenopterids, because the whales are easier to see and because they gather at traditional locations during winter. Nevertheless, it has not yet been possible to estimate population abundances sufficiently precisely to allow trends to be detected with statistical confidence.

YONAH (Years of the North Atlantic Humpback Whale) is a research project designed to answer those questions by sampling all populations in the North Atlantic Ocean with standardized methods during a two-year period using two techniques relatively new to whale science, photographic identification (Hammond et al., 1990) and DNA-biopsy sampling (Baker et al., 1990) of individual whales. Other unique features of YONAH include simultaneous sampling of all known habitats used during summer by humpback whales in the entire North Atlantic Ocean for two consecutive summers; and intensive sampling on the winter range during the preceding and following winter seasons. Large sample sizes will provide substantially improved description of population abundance, distribution and interchange, for an accurate snapshot of the species ocean wide status.

YONAH requires international cooperation, because most humpback whales in the North Atlantic Ocean feed, migrate, overwinter and/or breed in waters under the jurisdiction of two or more countries. Furthermore, it would be difficult for one government to provide all the funding necessary for such a comprehensive project, and it would be nearly impossible for one research team to accomplish the synoptic sampling program within the time period necessary to achieve the program's scientific goals.

YONAH will benefit from large scale models of collaboration that have already been established. For example, in 1987, Denmark, the Faroes, Iceland, Norway and Spain collaborated in an extensive shipboard and aerial census of whales in the eastern North Atlantic that used scientists from 8 nations (Oritsland *et al.*, 1989).

A significant problem confronts workers using photo-identification or DNA-biopsy techniques to study long range migrations, population subdivision and oceanic abundance. Hammond (1986,1990) described how opportunistic methods used in many such studies may not sample all portions of a population equally owing to geographic, temporal and biological biases. A brief examination of shortcomings in samples currently available for regions of the North Atlantic Ocean is instructive.

Geographic biases include the following examples. Newfoundland's long coastline is seasonally home to most of the whales in the western North Atlantic, but no comprehensive photographic sampling has been carried out since Whitehead's pioneering studies (e.g. Whitehead et al., 1982; Whitehead and Glass,1985). Even those studies visited only a small portion of the coast and spread the work

over several years. The situation in Iceland is even more difficult. The conclusions that whales from Iceland's Denmark Strait form a separate feeding aggregation and visit the West Indies to breed (Katona and Beard, 1990) were drawn from a sample of only 20 whales. Luckily, 4 of them were subsequently sighted on the winter range and one returned to Iceland during a subsequent summer. At the other extreme, the Gulf of Maine, a relatively small region seasonally inhabited by somewhat fewer than 500 whales, each year produces thousands of photographs. However, most of those photographs are taken by naturalists or scientists working mutualistically with commercial whale-watch boats, whose working range is usually constrained by the 4 to 5 hour length of scheduled trips. Consequently, relatively accessible locations are sampled disproportionately. Mitchell and Reeves' (1983) early concern that photo-identification studies have not fully determined the boundaries of the populations sampled is still true.

Temporal biases also exist. For example, most photographs in the Gulf of Maine are obtained from April 15 to October 15, the season when commercial whale-watch boats operate. Whales that appear early, perhaps on the way to other feeding aggregations, or whales that stay late, perhaps remaining throughout winter, do not have an equal opportunity to be photographed, particularly if they occur offshore. Disproportionate sampling during summer months is a common feature of studies throughout the North Atlantic. Larger scale temporal inequalities in sampling intensity also occur. For example, entire regions may be sampled during some years, but not others.

A suite of interesting biological biases also exist, such that different age classes, reproductive classes or genders may be over- or under-represented in samples. Resulting problems can be particularly vexing if sampling methods used in different regions cause different types of biases. For example, sampling on the winter range has focused on surface active courtship groups, which present more opportunities for photographing flukes than do mothers with calves or single whales. Since such groups are predominantly male, photographs of that gender may be over-represented. On the other hand, singing whales, thought to be only males, remain submerged for up to 30 minutes, and are likely to be sampled less than other classes. Similarly, a female accompanied by a calf flukes up less often than do other animals, particularly on the winter range. Calves photographed on the winter range are normally excluded from calculations of abundance, because they rarely fluke up and their fluke pigmentation patterns are not yet clearly formed.

Awareness of these biases and recognition that international cooperation would be needed to eliminate them led to the idea for a carefully designed, intensive synoptic investigation of all humpback whale habitats in the North Atlantic Ocean. A research proposal was prepared by scientists from 6 nations (see Acknowledgements) and submitted to the International Whaling Commission (Document SC/40/025) and the Marine Mammal Committee of the International Council for Exploration of the Sea (ICES) (C.M 1990/N:18).

Major goals of YONAH are:-

1. Photographs for individual identification will be obtained from approximately 1500 whales on the summer range during each of two successive summer seasons and 2000 whales on the winter range during the previous and intervening winters. Biopsy samples are anticipated from about half of those animals. Standardized protocols will be used to select areas in the summer range for searching, locate whales or groups of whales, select individual whales from groups for photographic or DNA sampling, and to terminate activity with a whale if samples have not been obtained within a reasonable amount of time. The overall sampling objectives will be to equalize the opportunity for every individual whale to be sampled, compensate for any inequalities in resulting analyses, and achieve precise confidence intervals by obtaining sufficiently large sample sizes.

2. Individual-identification photographs will be centrally archived and analyzed as described by Katona and Beard (1990), in order to be comparable with previous results. Procedures will be developed for providing appropriate access to photographic samples for YONAH collaborators or other interested scientists.

3. Protocol for processing and archiving biopsy samples will insure that at least half of each biopsy sample collected will be transferred to YONAH and used to determine gender of individuals; the number of matrilineal lines (haplotypes) present in mitochondrial DNA in the North Atlantic Ocean and their distribution in different subregions; and to identify nuclear gene sequences that would permit Mendelian analyses for delineating panmictic population

units. Additional studies for genetic fingerprinting and identification of paternal markers may be attempted after primary analyses are completed. Tissue remaining after primary analyses, along with appropriate descriptive data, will be preserved in a central archive at -80° C to insure its long term viability and availability. The YONAH organizing committee will welcome proposals for further analyses of tissue samples and grant permission for their use as appropriate, in consultation with the Project Coordinators for YONAH subregions involved.

4. A comprehensive centralized database will be constructed containing all information on individual photo-identifications, individual genetic data, sightings from which photographic and/or biopsy samples were attempted, and searching effort when locating groups of whales to sample. Data auditing checks will track and coordinate linkage of field and laboratory results so that no data are lost. YONAH collaborators will receive updated copies of the entire database periodically.

5. The YONAH database for the entire North Atlantic Ocean will be analyzed to estimate total population size and rates of exchange of whales between sub regions of the summer range. The representativeness of data collected at the regional level will be investigated and results used to modify methods for estimating population abundance. Likelihood models will be developed for estimating abundance and also for defining DNA haplotypes. Sensitivity analyses will also be conducted to determine the sensitivity of estimates of abundance and interchange to various assumptions.

6. Population abundance will be estimated by applying the Petersen capture-recapture method to individual-identification photographs. The planned sampling design, two successive seasons on the summer range (S_1 and S_2) along with the previous and intervening seasons on the winter range (W_1 and W_2) will permit several independent population estimates using either W_1/S_1; S_1/W_2; W_2/S_2, W_1/W_2 or S_1/S_2 as the capture-recapture samples. Estimates will be prepared for population subregions, including the Gulf of Maine, Gulf of St. Lawrence, Newfoundland, southwestern Greenland, Iceland, and Norway; and also for the whole North Atlantic Ocean .

This is an ambitious project. However, scientific interest is high and it dovetails nicely with some national and international goals of several countries. NMFS appears to be willing to support further planning for organization and development of scientific protocols. Proposals for additional funding are in preparation. Current hopes are that work at sea might begin by January, 1992.

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The discussion of the U.S. Humpback Recovery Plan summarizes my own experience. My comments do not necessarily represent views of the Recovery Team, NMFS or any agency or party other than myself. The Plan is still being discussed and evaluated by NMFS and some of the recommendations mentioned could be modified or eliminated before the Plan becomes NMFS policy. Copies of the Humpback Whale Recovery Plan and the Recovery Plan for Northern Right Whales can be obtained by writing to NMFS, Office of Protected Resources, 1335 East West Highway, Silver Spring, Maryland, USA 20910.

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